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Energy and labor intensity of manufacturing processes progressing toward sustainable development: A systematic literature review and SWOT analysis for a steel manufacturing company

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Abstract

Manufacturing, as one of the main pillars of a civilized lifestyle, will be strongly affected by sustainability issues, and it will play an important role in establishing a sustainable future. Within the area of sustainability issues, some specific issues are pointed out, such as the energy and labor intensity of manufacturing processes. The main aims of this paper are a systematic literature review and the evaluation of the energy and labor intensity of manufacturing processes in an industrial enterprise while proposing changes toward sustainable development. In the research, 163 scientific publications (77 related to China) were taken from the Web of Science (WoS) database based on selected keywords describing the studied phenomenon. The analyzed publications were divided into five areas (clusters). In terms of evaluating the energy and labor intensity of manufacturing processes, twelve production processes were selected, which were then grouped according to their most important areas of similarity (automation, ergonomics, and discomfort). The systematic literature review was carried out using the VOSviewer software, version 1.6.14. This article also uses the methodology of a case study with a simplified SWOT analysis based on interviews with employees and expert panels. The subject of the research is an industrial enterprise representing the steel manufacturing sector in Poland.

Introduction

Manufacturing, as one of the main pillars of a civilized lifestyle, will be strongly affected by sustainability issues, and it will play an important role in establishing a sustainable future. Today, nearly all manufacturing models are based on the old paradigm. Technology, on which manufacturing is largely based, is asked, together with culture and the economy, to devise tools and options for building new solutions toward a sustainable manufacturing concept. Generally speaking, new technology, business, and lifestyle models will be the cornerstones of the new sustainable world, and this will be particularly true for the manufacturing sector (Garetti & Taisch, 2012). Globally, the manufacturing sector is a major contributor to economic expansion and improvement in the standard of living. However, manufacturing processes have negative impacts on the environment and society as they consume excessive scarce resources and produce hazardous wastes and emissions (Saad, 2018). Manufacturing companies are facing the need to adopt new strategies, such as sustainability so that they can respond to the market and customer's demand for sustainable products due to the scarcity of natural resources or government policies (Eslami et al. 2019).

Within the area of sustainability issues, this paper focuses on some specific issues, such as the energy and labor intensity of manufacturing processes. Economic growth is often associated with high energy consumption, and energy intensity may bring about and exacerbate a variety of negative external production impacts, including environmental pollution and global warming, which has become a principal threat to sustainable development (Wang, Lee & Li, 2022, Luken & Castellanos-Sil, 2011). The literature in the field of energy economics has proposed some factors affecting energy intensity (Wang, Lee & Li, 2022), e.g., per capita income (Jimenez & Mercado, 2014; Agovino, Bartoletto & Garofalo, 2019), technological innovation (Wurlod & Noailly, 2018), urbanization (Farajzadeh & Nematollahi, 2018), trade openness (Rafiq, Salim & Nielsen, 2016), financial development (Pan et al., 2019), and energy prices (Karimu et al., 2017; Tajudeen, 2021).

When it comes to labor intensity, post-growth economists propose structural changes toward labor-intensive services, such as care or education, to make the economy more sustainable by providing meaningful work and reducing the environmentally damaging production of material goods (Hardt et al., 2020). Hami et al. (Hami, Muhamad & Ebrahim, 2015) wrote that companies need to re-establish their corporate strategy by introducing and implementing more integrated sustainable practices. Prior researchers believed that sustainable manufacturing practice (SMP), defined as a firm's intra- and inter-organizational practices that integrate environmental, economic, and social aspects into operational and business activities, would lead to better firm performance. Due to regulatory and market pressures, large-sized manufacturing enterprises have started reporting their sustainability efforts as per established guidelines. Small and medium-sized enterprises (SMEs), on the other hand, play an even greater role in optimizing the economic structure and social stability of developed and developing economies. Ironically, they struggle more to expand and to communicate their sustainability efforts to their stakeholders (Prashar, 2019).

Taking into consideration the above, work on implementing sustainability principles and procedures in manufacturing companies is still needed to achieve Sustainable Development Goals (SDGs). Thus, the content of this article is dictated by the research plan that is part of the implementation doctorate titled "Creating innovation and sustainability of the company with the use of multi-criteria decision support methods." To develop the decision-making model, the author defined three decision-making areas concerning:

1. The assessment of individual product groups in terms of the effectiveness of the use of raw materials and waste management.
2. Optimization of the production process in terms of energy and labor consumption.
3. The assessment of suppliers in the company's sustainable supply chain.

This paper analyzes the second area. The author analyzes the topic of optimization of the production process in terms of energy and labor consumption toward sustainable development from two points of view:

- bibliographic analysis;
- simplified SWOT analysis in the industrial enterprise that was the subject of the implementation doctorate.

Therefore, the main aims of this paper are a systematic review of the literature in the context of the occurrence of keywords relating to the energy and labor intensity of manufacturing processes and sustainable development in the English-language literature and the evaluation of these processes in an industrial enterprise, while proposing changes toward sustainable development.

The research questions regarding the systematic literature review concern:

- finding out how often the indicated keywords are cited, collectively and considered separately?
- how is research on this subject divided into research areas (so-called clusters)?

The SWOT analysis involved finding the answers to the following questions:

- what are the groups of production processes that should be analyzed regarding the energy and labor intensity of manufacturing processes?
- what are the strengths, weaknesses, opportunities, and threats for these processes with regard to sustainable development?
- what should be the directions toward sustainable development for the analyzed enterprise?

It should be noted that this manuscript identifies elements of the manufacturing process connected with sustainability with a focus on environmental issues. Societal and economic issues regarding sustainability are indeed equally crucial but are outside the scope of this manuscript. Also, in the case of the optimization of the production process in terms of energy and labor intensity, energy intensity was treated as electricity or heat consumption, considering recovery and losses, and the workload was assessed from the perspectives of discomfort, risk, and negative factors (especially in terms of the ergonomics of workplaces and occupational health and safety). The subject of the research is one of the well-established industrial enterprises representing the steel manufacturing sector in the West Pomerania region in Poland.

Systematic literature review – the methodology and results

The research procedure used in this study included several stages. In the first of them, 163 scientific publications were taken from the Web of Science (WoS) database based on selected keywords describing the studied phenomenon. Table 1 shows the results of the WoS database search. Studies in which the title, abstract, or keywords contained references to the terms energy intensity, labor intensity, manufacture, and sustainability were considered.

In the set of data separated in this way, the most frequently repeated terms appearing in the titles of abstracts and keywords indicated by the authors of the researched studies were searched for. VOSviewer software, version 1.6.18 was used to identify them. Figure 1 shows the connections between the identified keywords (those with at least six co-citations were considered) that formed five clusters.

In the first cluster (red), connections between the following keywords were identified: emissions (carbon-dioxide, CO_2, greenhouse-gas), decomposition analysis, driving forces, economic growth, energy policy, energy consumption, lmdi.

The second cluster (green) describes the connections between such terms as: decomposition and divisia index, drivers, efficiency, emissions, intensity, manufacturing sector, and policy.

The third cluster (blue) was created by the connections between the terms concerning: energy consumption, manufacturing, sector, productivity, and sustainable development.

Table 1. The results of the research provided on the basis of the publications indexed in the WoS according to the selected keywords (the author's elaboration based on WoS database)

The combinations of topics	Number of papers
"labour intensity" AND manufactur* AND sustainab*	7
"energy intensity" AND manufactur* AND sustainab*	157
"labour intensity" AND manufactur* AND sustainab* OR "energy intensity" AND manufactur* AND sustainab*	163

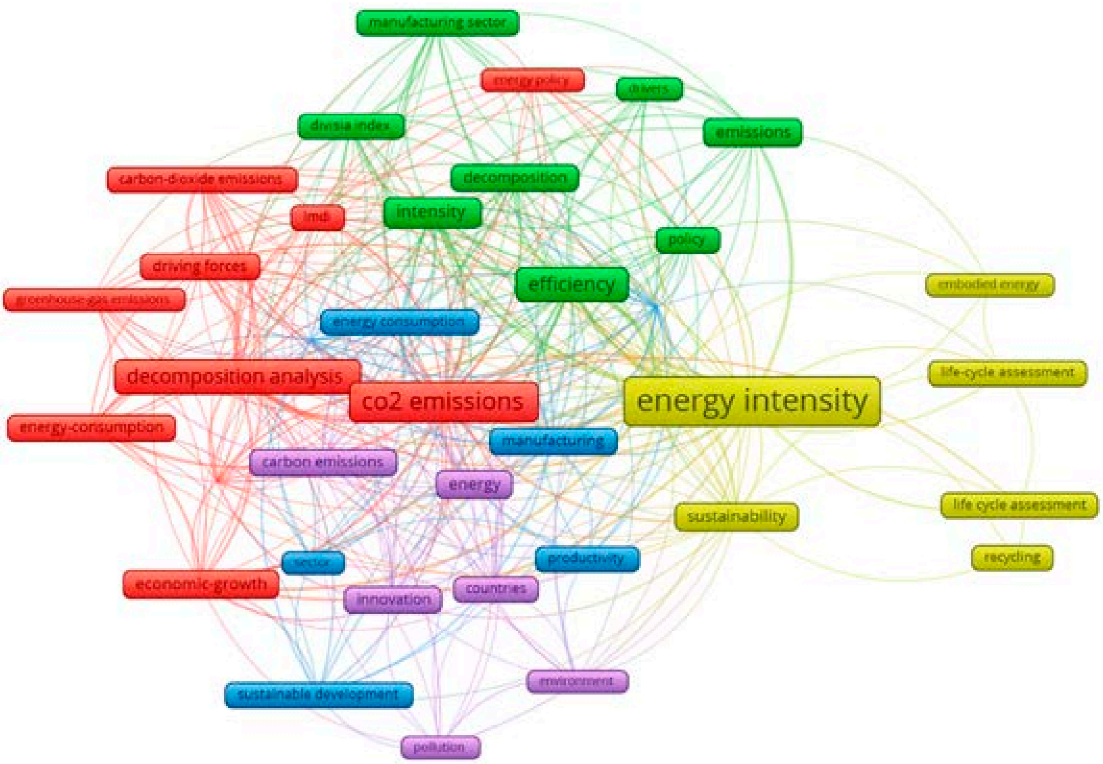

Figure 1. Clusters network (the author's elaboration in VOSviewer software)

In the fourth cluster (yellow), the key elements are the connections between the terms: energy intensity and such words as: embodied energy, life cycle assessment, recycling, and sustainability.

The fifth cluster (purple) describes the connections between the words: carbon emissions, countries, energy, environment, innovation, and pollution.

It is worth noting that in the selected clusters, terms referring to energy use and the adverse environmental impact associated with various types of emissions, such as CO_2, greenhouse gases, etc. dominate.

Among the publications that deal with this type of issue, one can mention, for example, papers by the following authors: Chontanawat et al. (Chontanawat, Wiboonchutikula, & Buddhivanich, 2014), El Anshasy and Katsaiti (El Anshasy & Katsaiti, 2015; 2016; 2018), Torrie et al. (Torrie, Stone & Layzell, 2016), Kim (Kim, 2017), Pardo Martinez and Silveira (Pardo Martinez & Silveira, 2013), and Zhang et al. (Zhang et al., 2019).

There are also many studies in which attempts have been made to identify various types of factors determining the intensity of energy use, including analyses involving the decomposition of such use into its constituent parts. Such analyses have been presented in the following studies: Anctil et al. (Anctil et al., 2011), Sorrell et al. (Sorrell et al., 2012), Ma et al. (Ma, Wang, & Chen, 2013) and Cheb and Liu (Chen & Liu, 2021).

The created database of 163 scientific papers was used in the next stage of the study to identify papers in which there were simultaneous references to a greater number of duplicate keywords. After reviewing the collected studies (their titles, keywords, and abstracts), it was found that there were many of them that described the results of the analyses in terms of particular geographical regions; these were also studies focused on identifying factors that determine outcomes, such as the level of unfavorable emissions and the effectiveness of the technologies used, while also referring to sustainable development. This information was used to build the following six binary variables with two categories of "yes" and "no", which were most often repeated in the studied publications:

- X_1 – region (1, if the information described in the paper was presented in terms of regions, including a combination of several countries in a given geographical region; 0, in the other case);
- X_2 – country (1, if the research results presented in the study were analyzed at a higher aggregation level than the region; it could refer to individual countries as well as continents, such as Europe or Asia, or groups of countries, e.g., the European Union; 0, in the other case);
- X_3 – factor (1, if the study analyzed the various factors, drivers, or determinants most often determining the intensity of energy use; 0, in the other case);
- X_4 – decomposition (1, if in the discussed considerations the decomposition method was used, including the use of, for example, the Divisia Index; 0, in the other case);
- X_5 – sustainable development (1, if direct references to sustainable development were identified in the analyzed studies, i.e., those in which sustainable development was an important element of the study; 0, in the other case);
- X_6 – emission (1, if the analyzed studies references to various negative effects related to human activity; 0, in the other case).

Table 2 presents information on the number of papers containing the indicated individual keywords.

Table 2. The results of the identification of the number of papers containing the analyzed keywords

Keywords	Number of papers
region	39
country (China)	105 (77)
factor	64
decomposition	57
sustainable development	80
emission	83

The review of publications indexed in the WoS database shows that out of 163 papers, 39 concerned analyses carried out at the regional level. Examples of these were studies by such authors as:

- El Anshasy and Katsaiti (El Anshasy & Katsaiti, 2015), investigated the causes of unsustainable growth in energy consumption and environmental degradation in the six Gulf Cooperation Council (GCC) countries. This study analyzed the long-term relationship between per capita CO_2 emissions and energy intensity in the GCC;
- Haukioja et al. (Haukioja et al., 2018), constructed smart specialization indicators for LAU-1 regions in Finland, i.e., for the 70 Local Administrative Unit level 1 (LAU-1) sub-regions in Finland. In the study, the authors used three smart specialization indicators: the Herfindahl-Hirschman Index for regional resilience (HHI), the regional relative specialization index (RRSI) based on the Balassa-Hoover Index (B-H), and the relative

employment volume index in the manufacturing sector (LIMI);
- Tavakoli et al. (Tavakoli et al., 2016), presented a top-down model of equity for the allocation of GHGs emission (such as GERA) for Iran, but at a provincial level.

A total of 77 papers about China have been identified. However, studies on energy use, energy efficiency, and the effects of energy consumption on the environment, where mainly various negative aspects related to the emission of substances harmful to human health were described, were presented in as many as 83 papers, among them papers by authors such as Li (Li, 2022), Azhgaliyeva et al., (Azhgaliyeva, Kapoor, & Liu, 2020), and Zhang et al. (Zhang et al., 2019).

The list of papers in which connections between the words sustainable development and emission were identified (Table 3) is interesting. Such connections were identified in 52 studies by authors such as Savona and Ciarli (Savona & Ciarli, 2019), Zhang et al. (Zhang et al., 2019), Azhgaliyeya et al. (Azhgaliyeya, Kapoor, & Liu, 2020), and Yu et al. (Yu et al., 2021).

Table 3. Cross-tabulation for variables: sustainable development and emission

Sustainable development	Emission		Summary
	Yes	No	
Yes	52	28	80
No	31	52	83
Summary	83	80	163

It is also worth paying attention to the relationships between the terms factor (driver) and decomposition. Table 4 shows the distribution of studies that include these types of keywords in the prepared database.

Table 4. Cross-tabulation for variables: factor and decomposition

Factor	Decomposition		Summary
	Yes	No	
Yes	40	24	64
No	17	82	99
Summary	57	106	163

As can be seen from the presented list, in 40 out of 163 analyzed publications there were simultaneous references to the indicated terms. Among them were the studies: Lin and Du (Lin & Du, 2014), Dehning et al. (Dehning et al., 2017), Zhang et al. (Zhang et al., 2019), and Dolge and Blumberga (Dolge & Blumberga, 2021). These were publications important for the analyzed research topic. They most often presented the results of research conducted with the use of advanced statistical and mathematical models.

Dehning et al. (Dehning et al., 2017) used a multiple regression model to determine the factors influencing the energy consumption of automotive plants. In turn, Lin and Du (Lin & Du, 2014) used two methods to identify and quantify the driving forces behind changes in energy intensity in Chinese provinces in 2005–2010, combining index decomposition analysis (IDA) and production-theoretical decomposition analysis (PDA). On the other hand, Zhang et al. (Zhang et al., 2019) used the Multiplicative Logarithmic Mean Divisia Index II (M-LMDI-II) method to analyze the factors influencing energy intensity changes in China's Shanxi Province. Yet another approach was used by Dolge and Blumberga (Dolge & Blumberga, 2021), who used the log-Mean Divisia Index (LMDI) distribution analysis to investigate how industrial energy-related CO_2 emissions in Latvia changed in 1995–2019. In the developed model, they considered five factors, including the effects of industrial activity, structural change, energy intensity, fuel mix, and emission intensity.

SWOT analysis for the steel manufacturing company

This research concerns a case study of one of the steel manufacturing companies in the West Pomerania region in Poland. The profile of the analyzed company is mainly subsidiary industrial production of metal structure components, prefabricated for external partners, according to their requirements and specifications.

One of the objectives of the implementation doctorate was to optimize the production process in terms of energy and labor intensity (consumption), where energy consumption was treated as electricity or heat consumption, considering recovery and losses, and the workload was assessed from the perspective of discomfort, risk, and negative factors (especially in terms of ergonomics, workplaces, and occupational health and safety).

To achieve this goal, the first step was to analyze the company's existing situation in the context of the analyzed issues. The author (a Ph.D. student) together with the Maintenance Manager conducted an inventory of all machines, devices, and production facilities, along with their electricity consumption and possible heat generation. The machines and devices, as well as objects related to individual technological processes, were listed in an ERP system. Under the supervision of the doctoral student, an **expert panel was established**, which included the Heads of Production Departments and the Technical Department, as well as Production Preparation and OHS services, to develop the widest possible view of energy recovery or loss in the production processes, the level of processing of raw materials, and the assessment of materials based on their cost share. Individual production processes in the total cost pool and the effectiveness of individual production processes were assessed during a **brainstorming session**, trying to determine the possibly wide set of employee burden criteria, especially in terms of occupational health and safety and the ergonomics of workstations. In the next step, the team plans to develop a matrix of connections between individual criteria, creating the largest possible number of connections and direct and indirect impacts with various areas of operation, and then to assign the force and probability with which impacts on employees and the production process can be expected. This set will be the basis for the creation of multi-criteria models in the future. At this stage, the author performed a **SWOT analysis** to determine the strengths and weaknesses of the analyzed enterprise, as well as opportunities and threats concerning the discussed topic.

Departments and production areas

A number of machining processes were carried out at the MABO I, MABO II, and MABO III, Tooling, Hardening, Plastic Working, Galvanizing, and Painting departments. These processes differed in many aspects, such as energy consumption, automation, ergonomics of the workstation, and inconvenience for the operator. Twelve production processes were selected, which were then grouped according to the most important areas of similarity: automation, ergonomics, and discomfort.

Group I (unergonomic processes)

- Processes of manual grinding after welding and surface treatment;
- Manual welding processes: MIG/MAG, TIG, MMA.

The analysis for group I shows that processes in this group are fairly manual, and the key factor is the low level of ergonomics of the workstation. These processes are the core for most of the products. The ergonomics of grinding and welding depend highly on the characteristics of the product's technical specification and customer requirements. This reason allows for a wide range of production with a very

Table 5. Factors for the SWOT analysis regarding the unergonomic processes (group I) in the analyzed enterprise

Strengths	S	SoI	Weaknesses	S	SoI
Ease of adaptation to the product – since the welding and grinding processes are performed manually by qualified employees, it is easy to perform short-series processes and produce significantly different products.	3	3	Low flexibility of production capacity	4	5
No downtime due to retooling	4	4	Efficiency directly proportional to the level of complexity and manual difficulty of a specific product	5	4
The emission of noise and vapors is directly proportional to the instantaneous production volume	3	3	Difficulty in estimating the amount of work (adequate allocation of human resources) at the stage of production preparation	3	4
Relatively low energy and heat consumption per man-hour of the process	4	4			
Opportunities	**S**	**SoI**	**Threats**	**S**	**SoI**
Qualified staff and relatively easy and cheap change of welding and grinding technology (by changing welding or grinding materials) allow for a very wide market share in the prefabrication of structures made of various types of metals.	4	3	High sensitivity to the labor market situation (especially for highly qualified welders)	4	5
The development of large-scale production will bring the potential for the implementation of welding robots, significantly reducing the burden of work for welders in the repetitive welding process	3	4	High saturation of the labor intensity of manual processes (especially grinding) in the situation of growing costs of remuneration of qualified employees creates the risk of an unpredictable increase in the costs of these processes, and thus a reduction in the competitiveness of the conducted production activity.	4	4

S – significance (1 – low, 5 – high); SoI – strength of influence (1 – low, 5 – high).

short time for set up or change-over. On the other hand, the only reasonable improvement would be robotization and automatization of the process, but that would only be possible for high-volume production with very little diversity in the production profile.

Group II (Complex processes)

- Cutting processes on band saws;
- Drilling processes on column drills;
- Cutting processes on CNC machine tools (lathes, milling machines);
- Plastic working processes (presses, benders, guillotines);
- Thermal cutting processes (CO_2 and fiber laser, plasma, gas burner).

In group II the key processes are CNC machining and cutting. All the processes are commenced on specialized machines with adequate safety and ergonomics. Since the company invests in the latest machining technology, energy consumption levels are also optimized. The main field for improvement is loading, including manipulation in loading and unloading, specifically of large and cumbersome pieces.

Group III (arduous processes)

- Airless painting process (wet painting shop);
- Abrasive blasting (sandblasting, shot blasting).

The analysis shows that in group III all the processes in this group are carried out manually in environments with high levels of discomfort. For the wet painting, harmful fumes are emitted, while high noise and harmful dust emission occur during sandblasting. Both processes are the key processes for surface treatment for the entire scope of carbon steel manufacturing production, and the key component of the added value of the company's final product. Due to the above reasons, the decision-making field and strategy should be the implementation of new less harmful painting formulations, such as water-based paints, and providing the latest personal protective equipment for operators.

Group IV (High-temperature processes)

These processes are similar due to high electricity and/or heat energy consumption:

- Powder coating process (powder coating shop);
- Hot dip galvanizing process;
- Hardening, tempering, and normalization (quenching) process.

All the processes in group IV are characterized by a high consumption of electrical energy and high emissions of harmful substances, both of which have a very negative impact on sustainability, cost-effectiveness, and the well-being of the operators. On the other hand, all the high-temperature processes are the key in building value for the final product, in many cases having key advantages from the manufacturing perspective. From the decision-making perspective, with the considerations of the cost of electricity, the

Table 6. Factors for the SWOT analysis regarding the complex processes (group II) in the analyzed enterprise

Strengths	S	SoI	Weaknesses	S	SoI
Automation of the loading process and manipulation of the processed detail in the processing field with the use of handling devices, such as overhead cranes, cranes, and gantry as well as forklifts, significantly reduce the discomfort of operators' workstations	3	3	Machining processes carried out on machine tools in an automatic manner and the additional use of manipulators reduce the discomfort of workstations for operators. Unfortunately, the risk of health and safety problems and discomfort increases in direct proportion to the size and weight of the processed products. It is related not so much to the machining process itself, but to close transport and placing the detail in the machining field.	3	4
All machining processes are carried out on machine tools made on the basis of international standards and machine standards, ensuring an adequate level of operator safety, a high level of health and safety, and low operator inconvenience.	4	3			
Opportunities	**S**	**SoI**	**Threats**	**SoI**	**S**
All machine tools for complex processes enable the processing of materials with increased anti-corrosion resistance, such as stainless steel or aluminum, which allows the creation of a profile of finished products with the reduction of energy-consuming, high-emission, and burdensome anti-corrosion surface processes, such as galvanizing and/or wet and powder coating.	3	4	Due to the need to have highly qualified operators for conducting production processes on complex process machine tools and due to the shortage of such personnel on the labor market, despite the high productivity of the machines themselves, the production capacity of the machining processes is significantly reduced due to the staff shortages.	3	3

S – significance (1 – low; 5 – high); SoI – strength of influence (1 – low; 5 – high).

Table 7. Factors for the SWOT analysis regarding the arduous processes (group III) in the analyzed enterprise

Strengths	S	SoI	Weaknesses	S	SoI
Wet painting and abrasive blasting processes, since they are performed manually by qualified employees, allow for easy adaptation to the product, production of short-series, and significantly different products.	4	4	The processes of wet painting and abrasive blasting, due to their nature, i.e., high emission of vapors, dust, and noise, are associated with great discomfort, particularly related to health and safety and the need for employees to constantly wear personal protective equipment.	5	4
The versatility of wet painting and abrasive blasting processes allows the downtime resulting from the conversion of stations to be minimized.	4	5	Wet painting and abrasive blasting processes, due to their high consumption of compressed air, which is produced in the enterprise by energy-consuming compressors, cause high energy consumption.	4	4
Opportunities	**S**	**SoI**	**Threats**	**S**	**SoI**
Innovations related to personal protective equipment and their implementation at the positions of operators of wet painting and abrasive blasting processes significantly reduce the negative impact of the environment and the discomfort of the work.	3	4	Most of the wet painting and abrasive blasting processes are highly energy-consuming due to the very high consumption of compressed air, which is highly energy-consuming to produce in compressors.	4	5
Innovations in the field of varnish materials and abrasives used in the processes of wet painting and abrasive blasting allow the process time to be shortened or air consumption to be reduced, which significantly reduces energy consumption.	4	3	All wet painting and abrasive blasting processes are associated with the emission of various substances, dust, or noise and are subject to environmental control and integrated emission permits, and the increasing environmental requirements and standards force continuous and high investment expenditures to reduce emissions.	4	3

S – significance (1 – low; 5 – high); SoI – strength of influence (1 – low; 5 – high).

Table 8. Factors for the SWOT analysis regarding the high-temperature processes (group IV) in the analyzed enterprise

Strengths	S	SoI	Weaknesses	S	SoI
Partially automated processes, improving and facilitating the work of operators, significantly reducing the risk related to health and safety and the discomfort of the work.	4	4	All high-temperature processes, due to their nature, i.e., high ambient temperature, emission of vapors, dust, and noise, are associated with great discomfort, particularly related to health and safety and the need for employees to constantly wear personal protective equipment.	4	5
Heat recovery, especially in the area of preliminary heating of the structure before painting and galvanizing, the use of heat to dry the structure in processes, and the accumulation of heat in the oil tanks of the hardening plant, allows for a significant reduction in energy consumption.	4	4	Due to large differences in process and ambient temperatures, high-temperature processes are characterized by large heat losses, which significantly affect the energy consumption of the processes.	4	4
Changing the technology of generating heat from electricity from resistance to induction technology causes a significant reduction in energy consumption	3	4			
Opportunities	**S**	**SoI**	**Threats**	**S**	**SoI**
Innovations related to personal protective equipment and their implementation at the positions of operators of high-temperature processes significantly reduce the risk related to occupational health and safety and the discomfort of the work.	3	4	Most high-temperature processes are highly energy-intensive with additionally having a low heat recovery coefficient (the exception is the hardening process and the use of heat to heat the hall in the winter months). The source of energy for these processes is electricity, and its significantly rising price could cause an exponential jump in the costs of these processes.	5	4
Innovations in the field of materials and chemicals used in some high-temperature processes, such as the pickling plant and powder paint shop, enable the speeding up of processes or their implementation at lower temperatures, which significantly reduces energy consumption.	4	3	All high-temperature processes are associated with the emission of various substances, dust, or noise and are subject to environmental control and integrated emission permits, and the increasing environmental requirements and standards force continuous and high investment expenditures to reduce emissions.	4	5

S – significance (1 – low; 5 – high); SoI – strength of influence (1 – low; 5 – high).

key is the scope of the competition: if it is local then it is mitigated by the fact that everyone on the Polish market will face the same circumstances. However foreign competition with lower costs of energy will have an advantage in pricing the product. So, in this case, the market of the end user should be recognized in the decision-making process.

Conclusions

Summarizing the conducted analyses, the author noted many criteria, premises, and conditions by means of which it is possible to evaluate individual production processes in terms of energy consumption or employee burden. For the sake of ordering, the production processes were classified based on common leading conditions referring to the premises of sustainable development. As a result, four groups of processes were created: unergonomic, complex, cumbersome (or arduous), and high temperature. In group I (unergonomic processes), the areas of similarity are automation, ergonomics, and employee discomfort, while the processes are manual grinding (after welding and surface grinding processes) and manual welding (MIG/MAG, TIG, or MMA). In group II (complex processes) the areas of similarity are automation, ergonomics, and arduousness, while the processes are cutting processes on band saws, drilling processes on column drills, cutting processes on CNC machine tools (lathes, milling machines), plastic working processes (presses, benders, and guillotines), thermal cutting processes (CO_2 and fiber lasers, plasma, and gas burner). The next is group III (arduous processes), where the areas of similarity are automation, ergonomics, and discomfort, while the processes are hydrodynamic painting process (wet paint shop) and abrasive blasting (sandblasting plant, shot blasting plant). The final group is group IV (high-temperature processes), where the areas of similarity are energy consumption (electricity and heat), while the processes are powder coating (powder coating shop), hot-dip galvanizing, and the processes of hardening, tempering, and normalization (quenching).

Each of the analyzed processes is characterized by different energy consumption, employee discomfort, or workplace ergonomics. In terms of decision-making issues, orders are selected for execution from the pool of inquiries flowing to the company, where the order portfolio predetermines the production processes necessary for prefabrication. Understanding the broad impact of various aspects of individual processes on the potential for sustainable development allows for appropriate planning decisions regarding the building of a portfolio of orders enabling the sustainable development of the company.

To sum up, the current situation of the company, considering the immediate and future environment, as well as the organization itself, its business model, and internal resources, does not allow for significant and drastic changes in the basic technological processes. Investment tasks, along with research and development activities, are carried out on an ongoing basis, and innovative potential is built in through subsequent implementation projects. Moreover, only a part of the company's production potential is used to produce its own products, and the remaining part of its potential is used for external orders based on the documentation and requirements of the client. Due to the above, only cumulative activities consisting in the continuous optimization of processes combined with modeling the portfolio of orders passing through the production space allow for synergy and the sustainable development of the company.

In the context of future research directions, the next research task in this area will be modeling with the use of multi-criteria decision support models aimed at supporting operational activities and decision-making processes for creating an investment policy, building a portfolio of orders, or creating further products.

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